Validation of Heliosphere Models

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Abstract

- The Community Coordinated Modeling Center (CCMC) performs validation studies for a variety of space weather models. In this presentation, we will present results on the validation of the Heliospheric Tomography Model developed by Bernard Jackson and Paul Hick. The Heliospheric Tomography Model makes use of interplanetary scintillation (IPS) to tomographically reconstruct the global structure of the solar wind density and velocity. We will present comparisons of the model results to ACE plasma data. In addition, we will present results from the model for the August 24, 2002 SHINE event.

Need for Metrics

- Create objective measure of current capabilities both for scientific and operational needs.
- Measure the improvement of model capabilities over time.
- Provide an objective comparison between models with comparable output.

  Metrics which lead to scores near unity now are useless!

Elements of a Metric

- An output parameter from a model.
  - Density or velocity at a satellite position
- A satellite or ground-based measurement that can be used for comparison.
  - Plasma data from ACE
- A quantifiable norm that assesses the difference between the parameter from the model and the measurement.

Heliosphere Metric

- Data
  - ACE velocity and density average every 6 hours for 27 days.
- Model
  - Heliospheric Tomography Model developed by B. Jackson and P. Hick. This model gives output every 6 hours for 27 days.
- Metric
  - A model is scored using $D_i = \text{sqrt}\,(\Sigma|\Delta H_{model} - \Delta H_{data}|^2/\text{npts})$.
  - A skill score is computed by

$$M_i = 1 - D_i / D_s$$

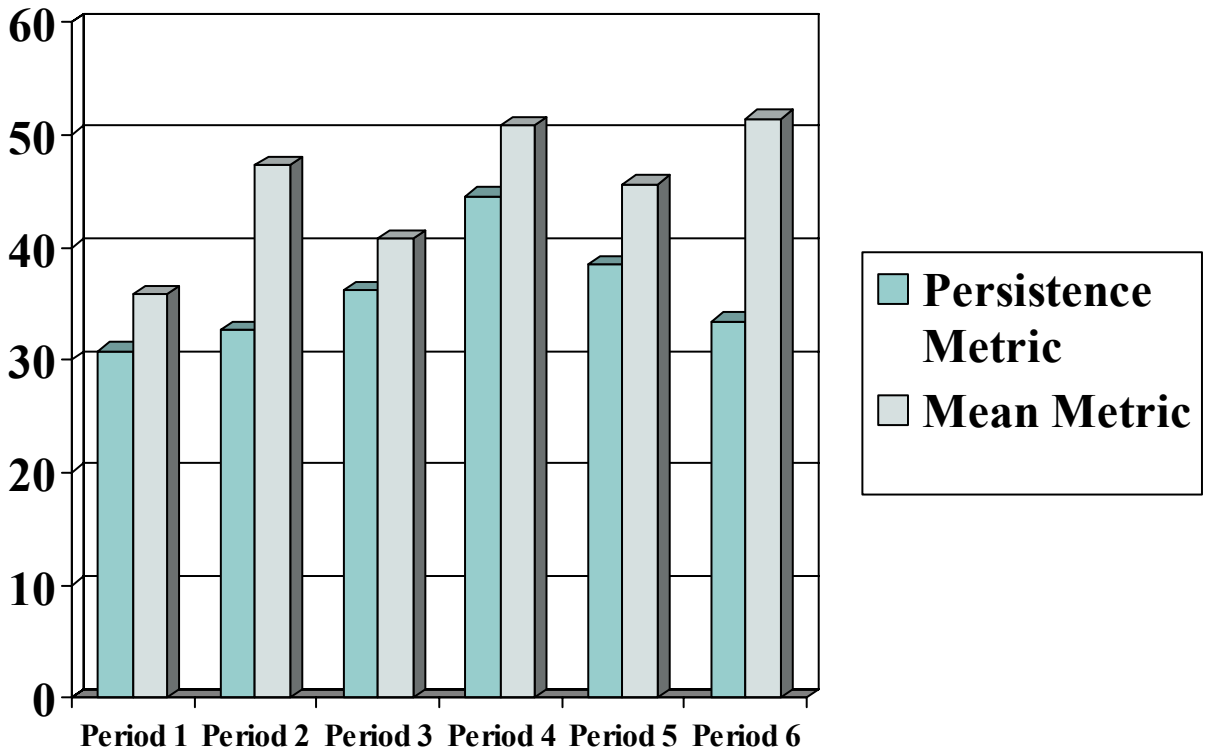
where D_s is for the standard model. In this case, two standard models were used. One standard is a persistence metric which uses the previous measurement as the prediction for the current time step. The second standard is the mean for the entire Carrington rotation.

  - The score is then scaled so that the score is between 0 and 100 by the following transformation $S_i = 50 * (2^{M_i})$. A score above 50 means that the model is doing better than the standard model.

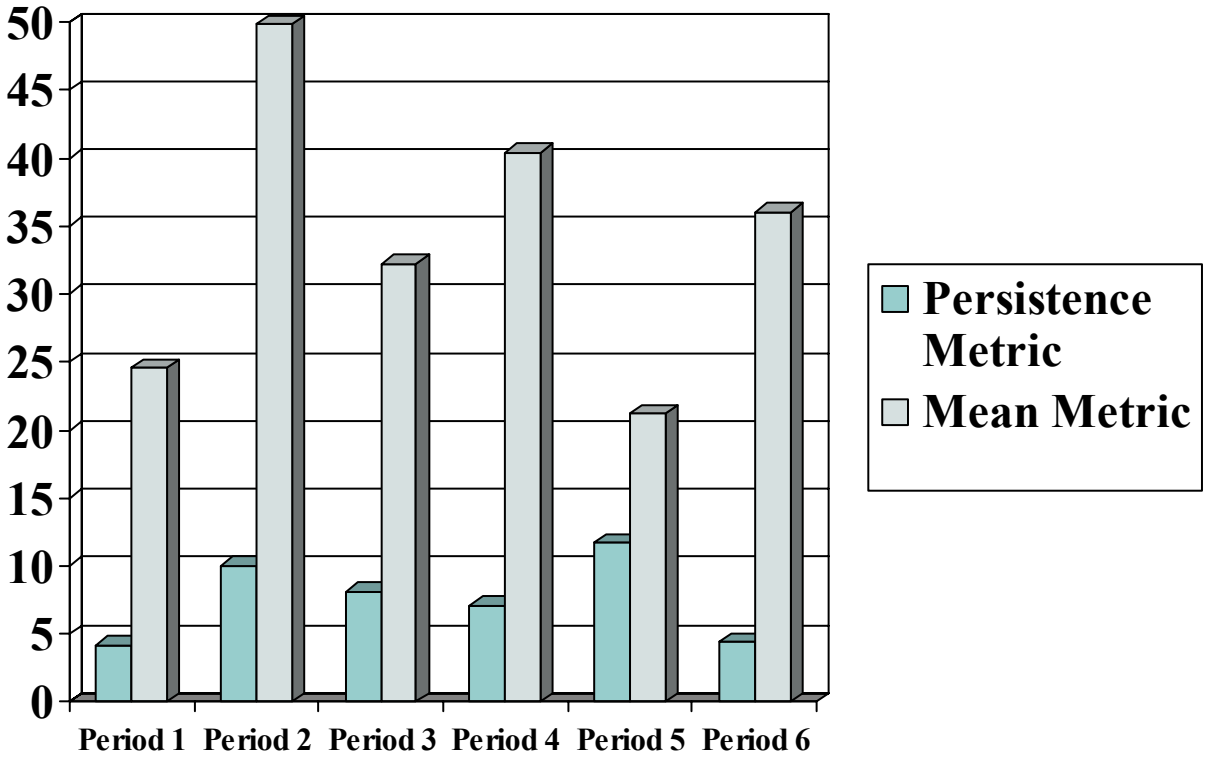
Heliospheric Tomography

- Kinematic model using conservation rules
- Density and velocity specified on source surface
- Using kinematic model, IPS velocity and g-level data are calculated by the model and compared with observations. Using an iterative least-squares algorithm, the source surface is updated to obtain the best model for the solar wind.

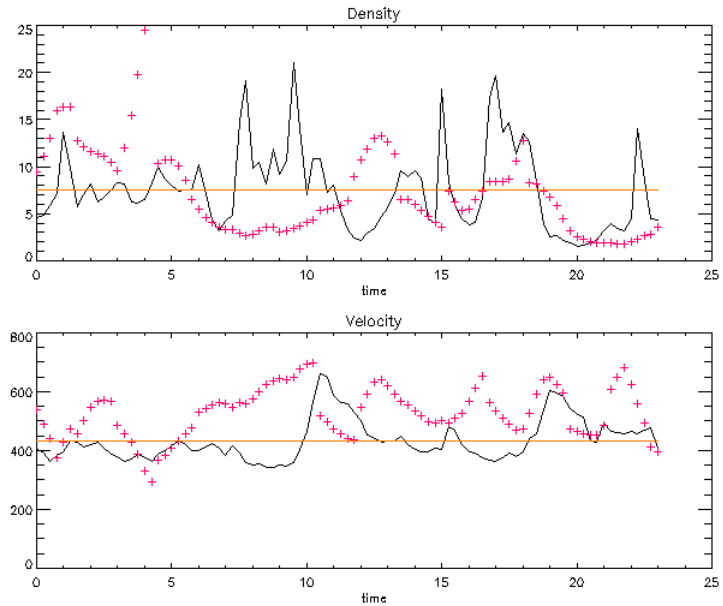
Scores for Density



Scores for Velocity

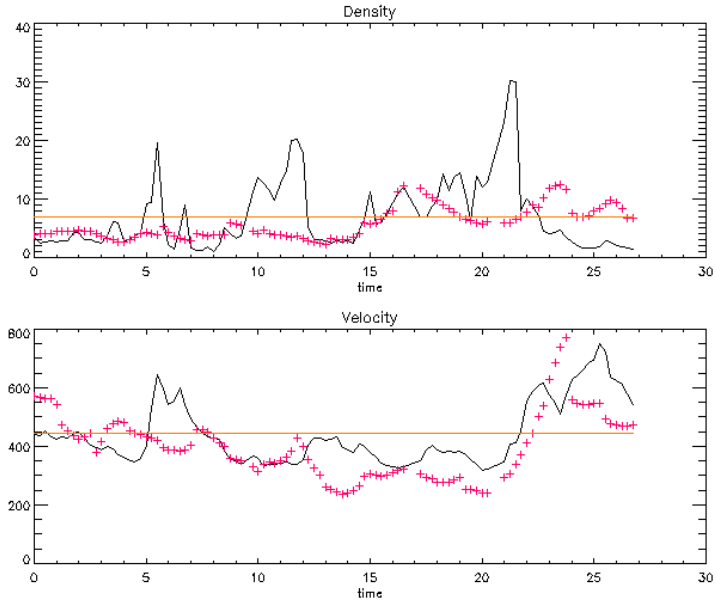


Model and Data Comparison



Time (Days)

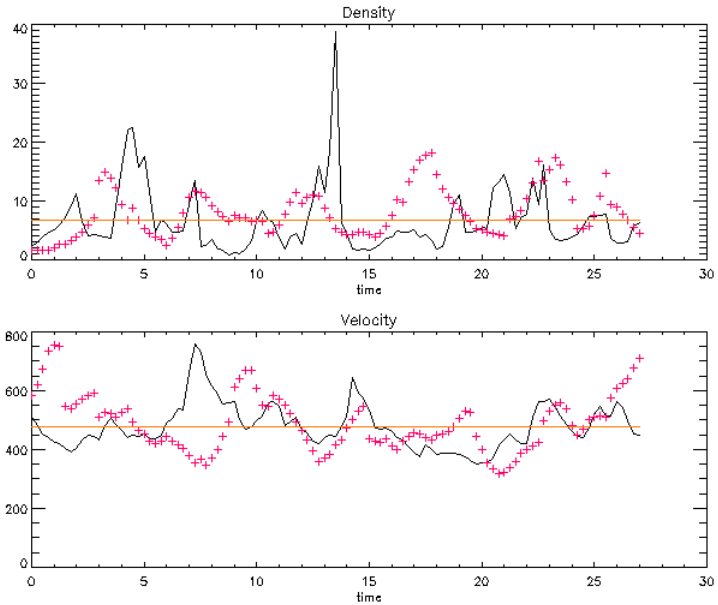
Period 1



Time (Days)

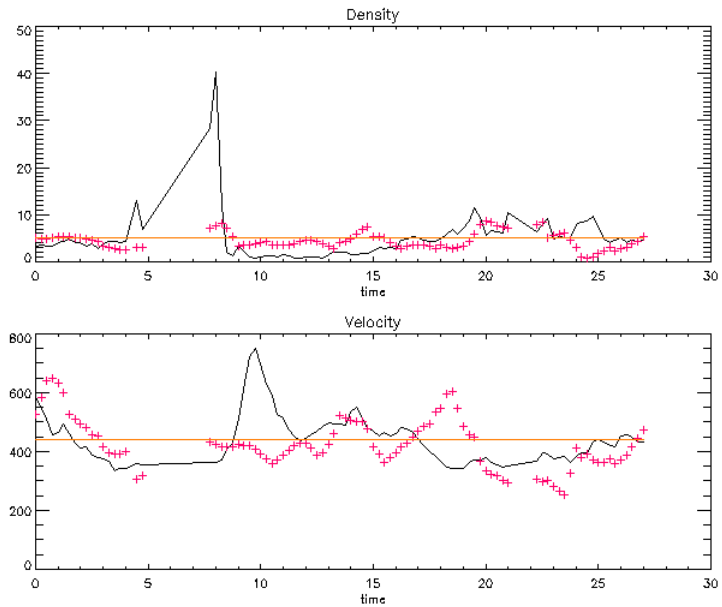
Period 2

Model and Data Comparison



Time (Days)

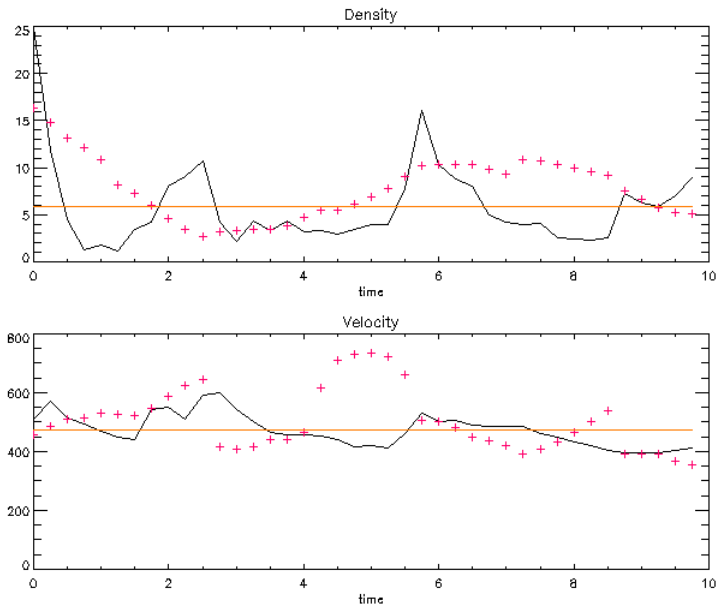
Period 3



Time (Days)

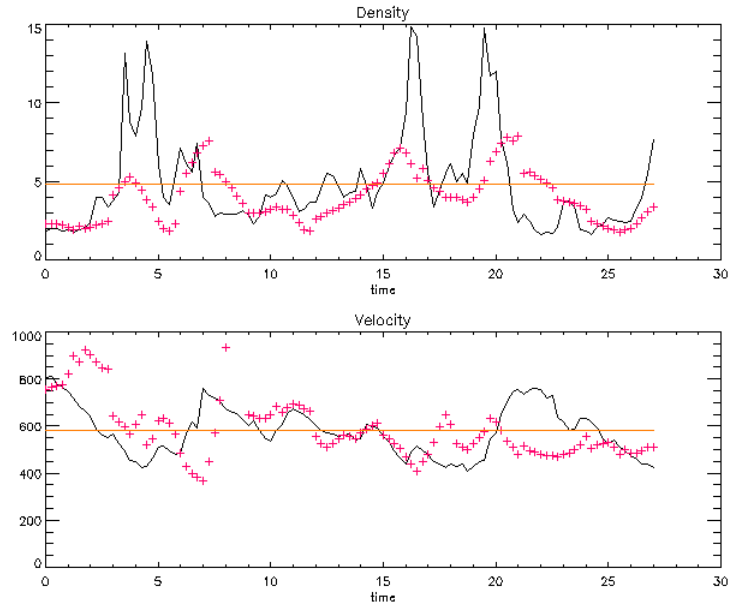
Period 4

Model and Data Comparison



Time (Days)

Period 5

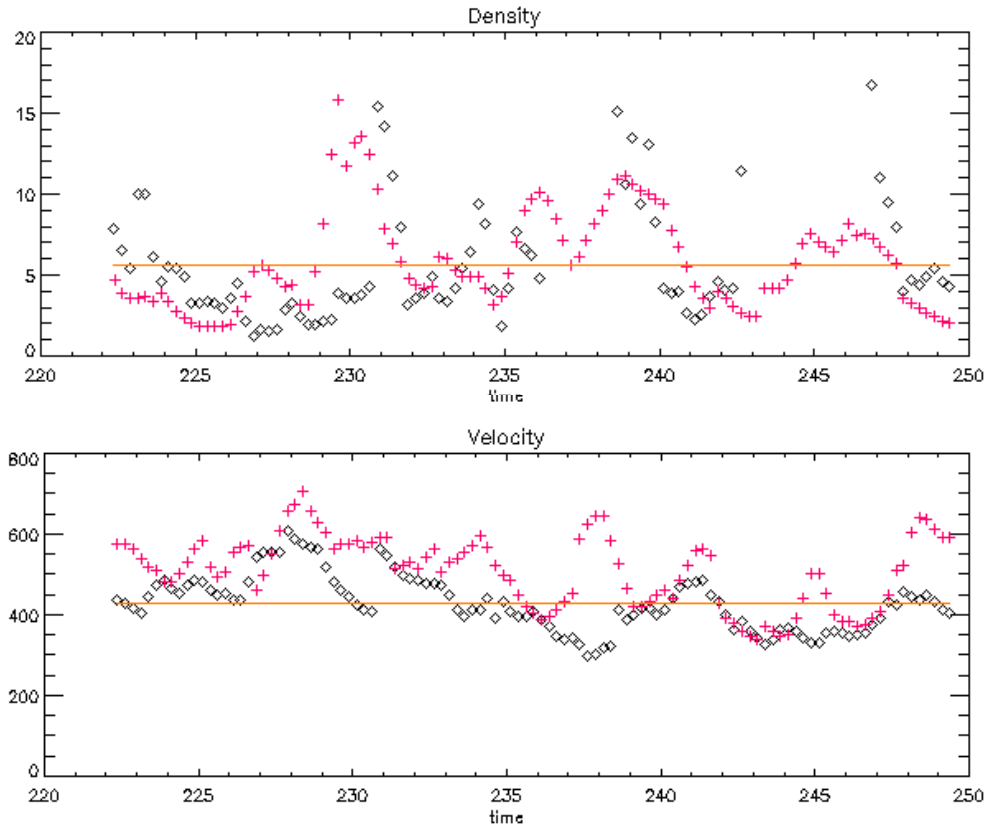


Time (Days)

Period 6

Only 38% of the period covered

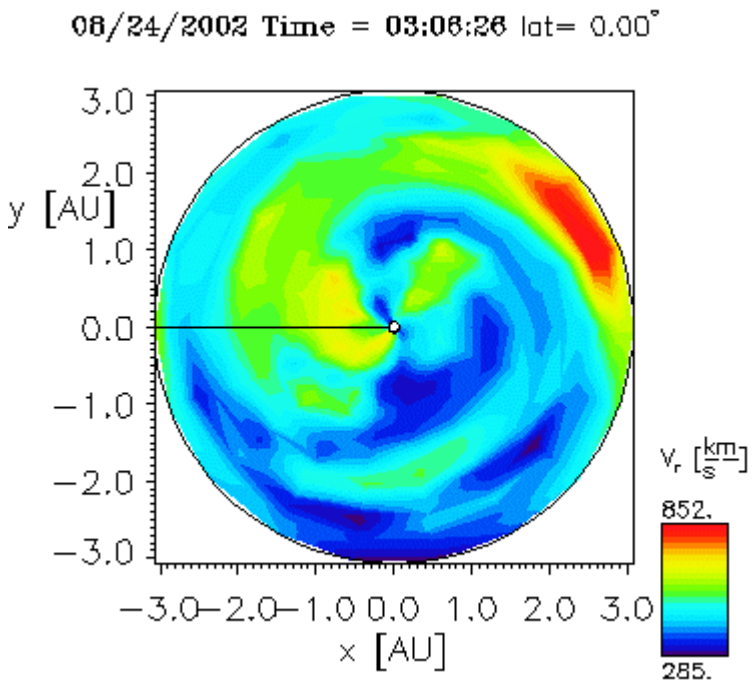
August 2002

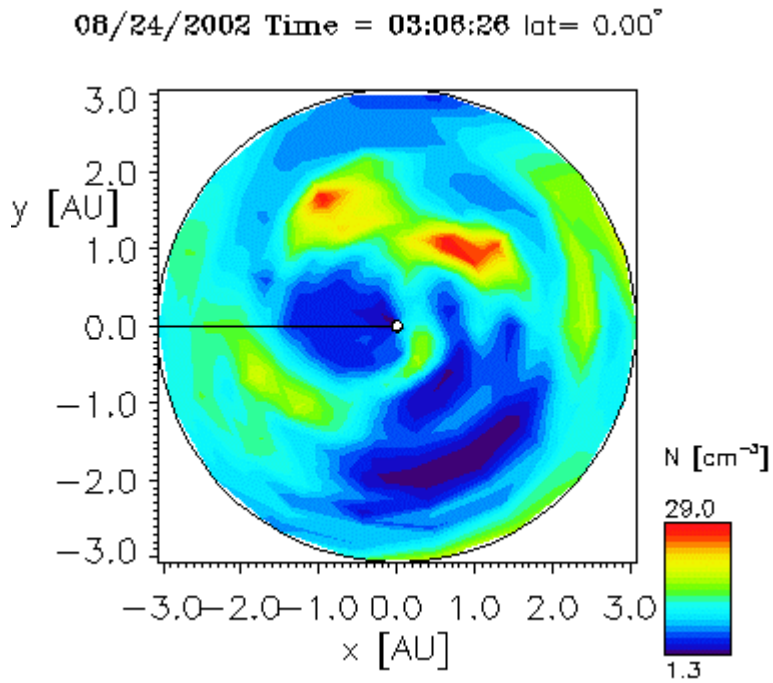


August 24, 2002

Day 236

August 24, 2002





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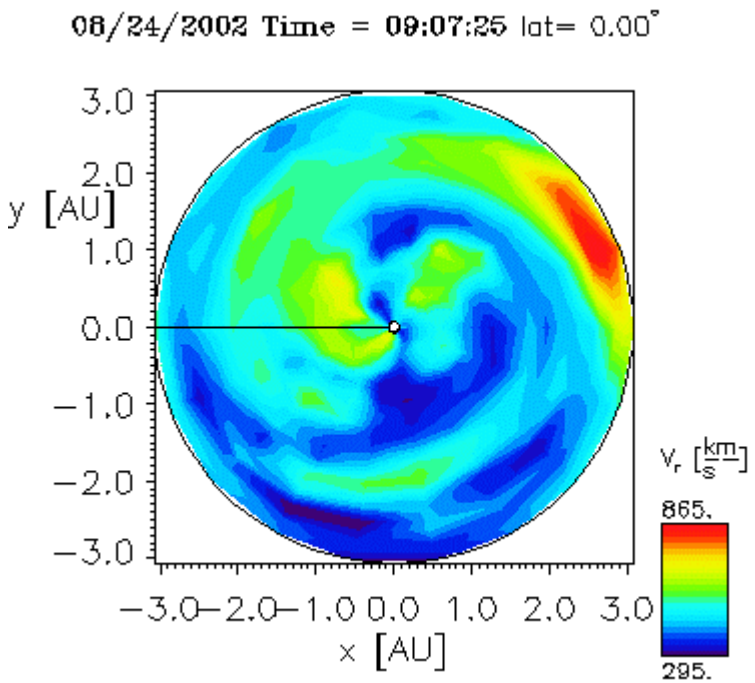

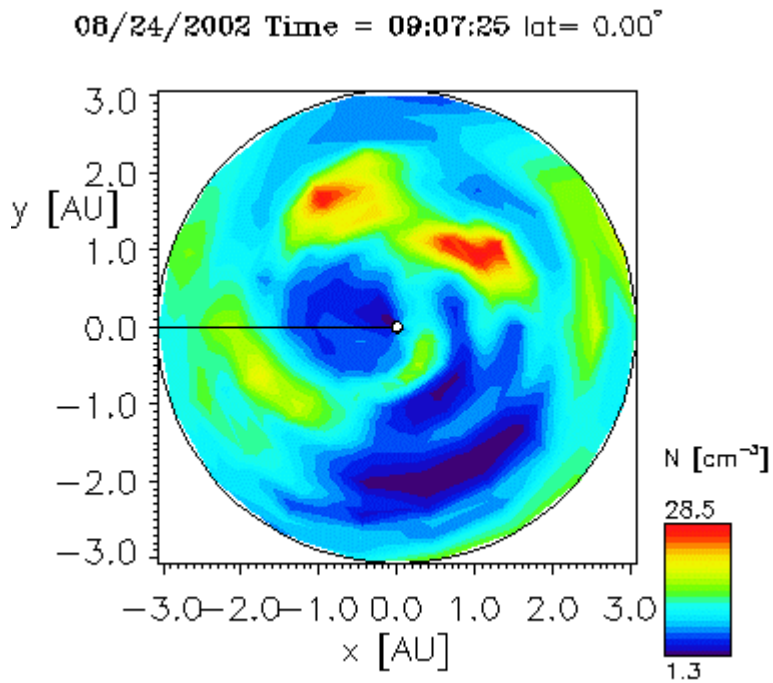

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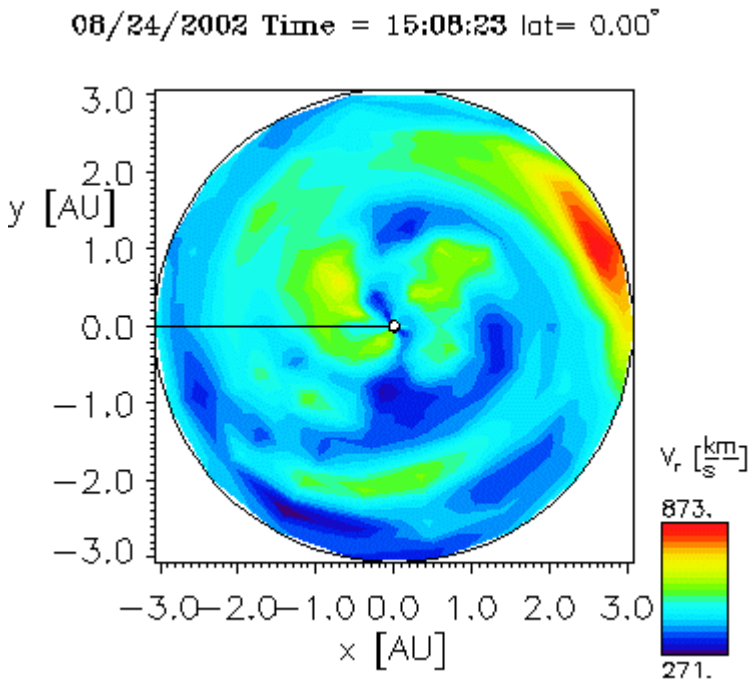

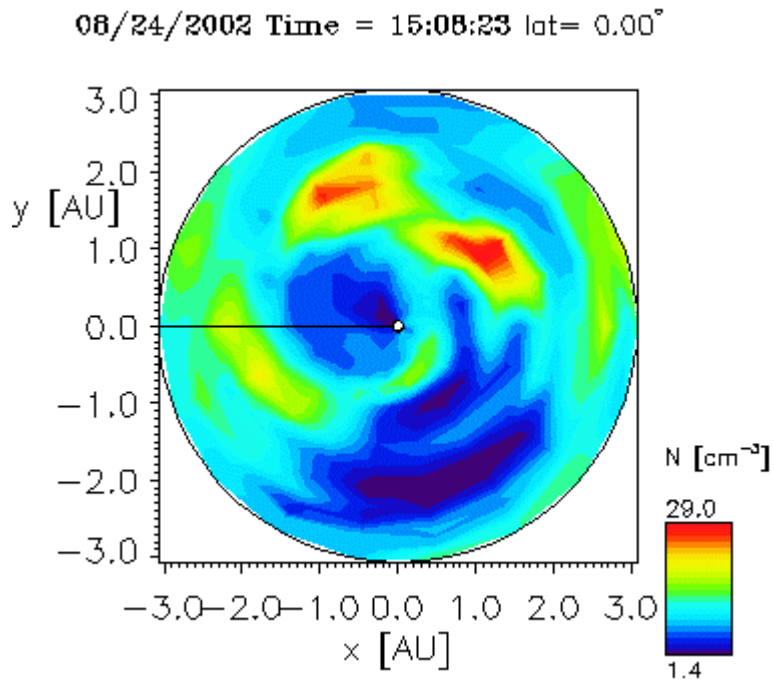

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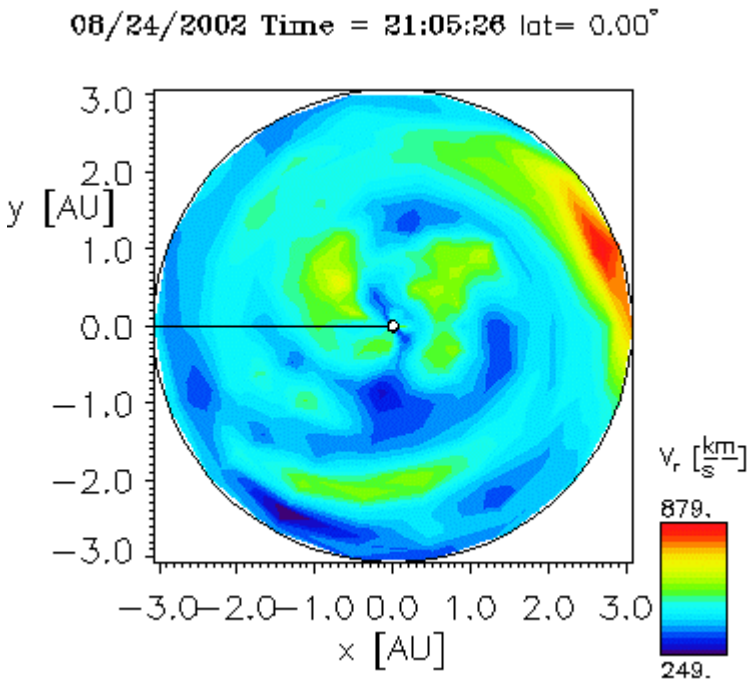
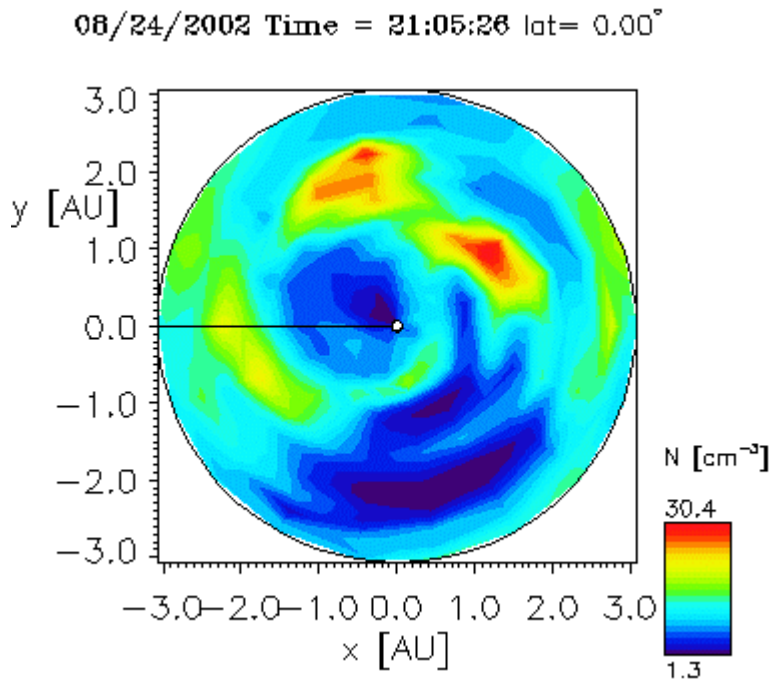
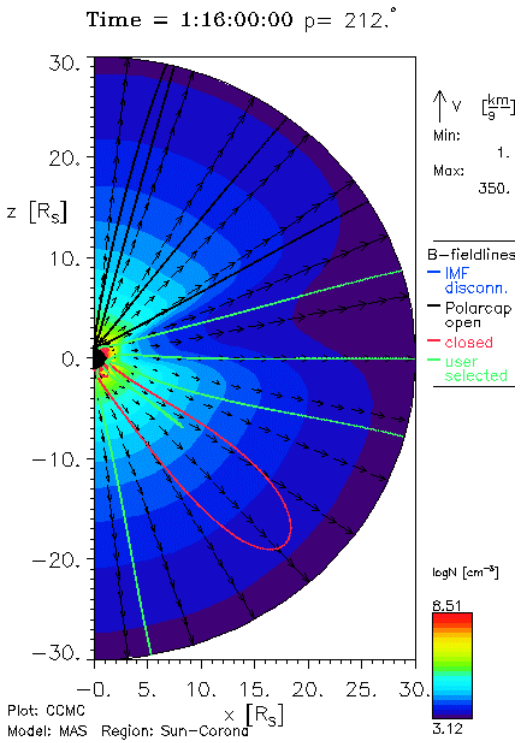


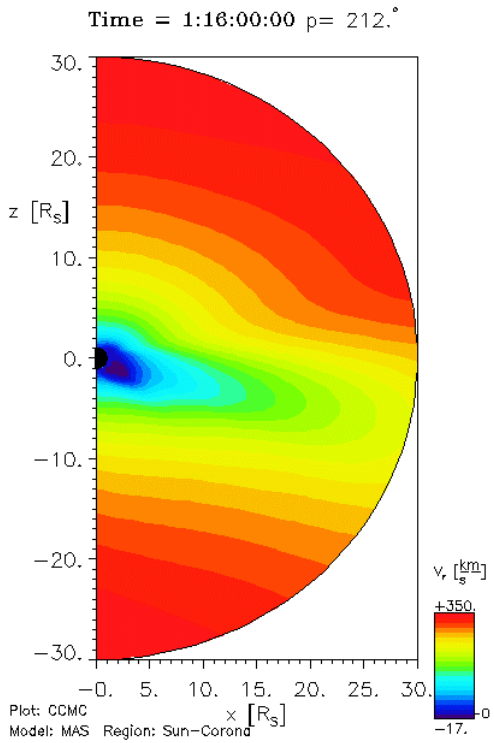


Solar MAS

- MHD equations
- Photospheric magnetic field data is used for the boundary condition on Br.
- Solved to steady state
- Input at Photosphere
  - Magnetic field (CCMC web site user enters date)
  - Density
  - Temperature
- Output
  - Magnetic field
  - Velocity
  - Density
  - Temperature

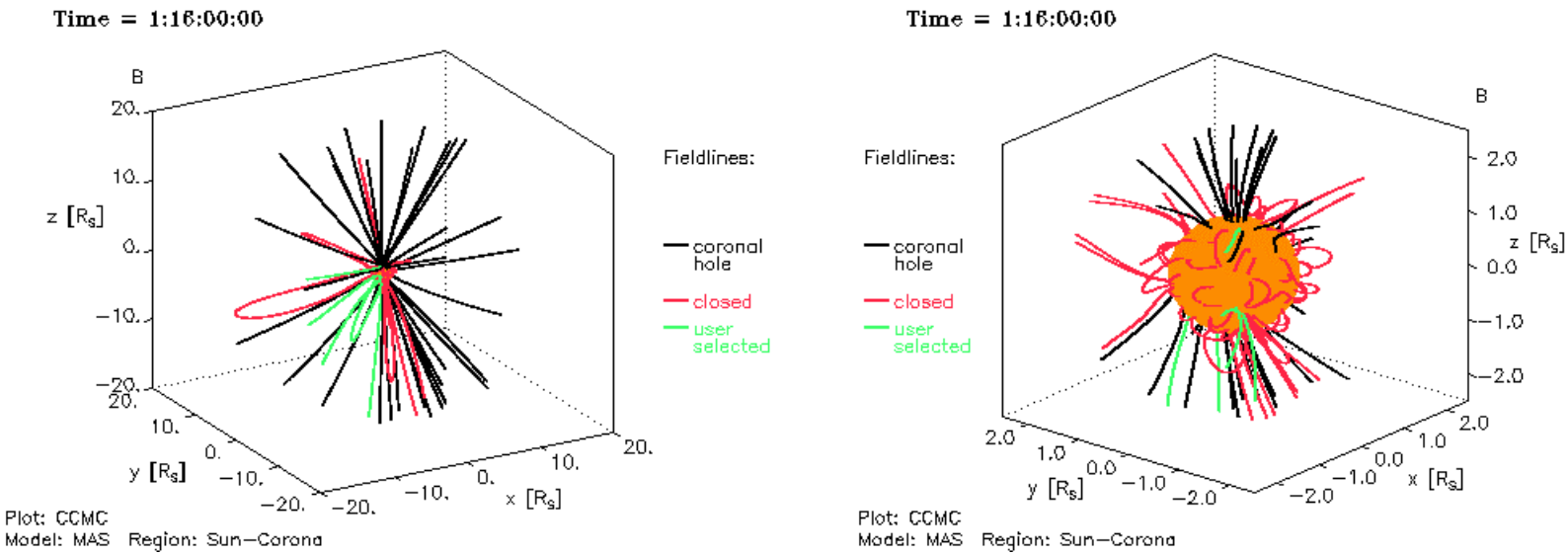
Solar MAS





Carrington Rotation 1993

Solar MAS

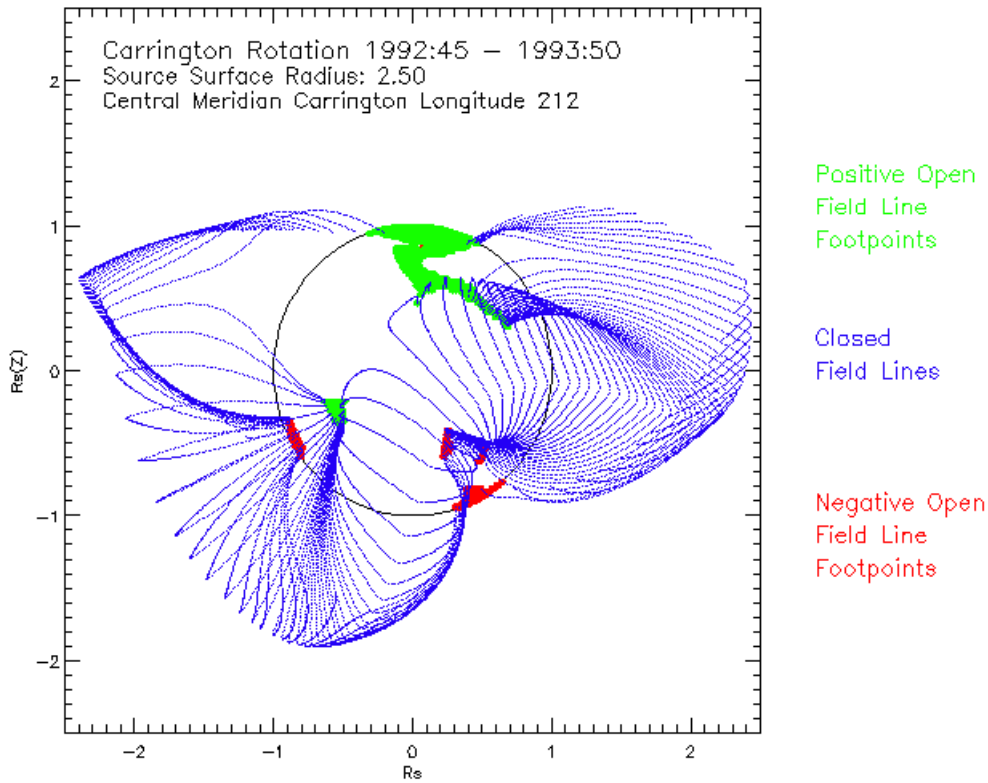


Carrington Rotation 1993

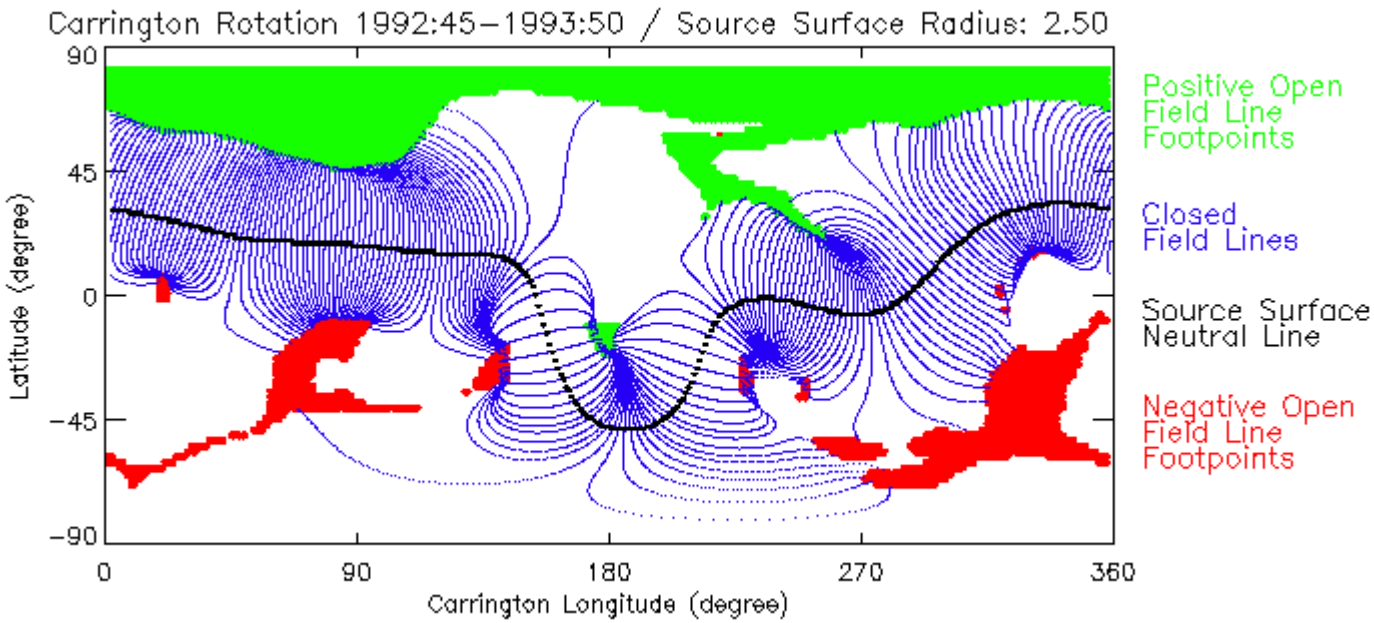
Potential Source Surface Model

- The model calculates the magnetic field of the corona from the radius of the sun to the source surface radius assuming that there are no currents in this region.
- The code uses spherical harmonic coefficients calculated by Wilcox Solar Observatory using observed photospheric fields (magnetograms) as input.
- User input:
  - Date
  - Source Surface Radius (1.6 – 3.25 R_s)
  - Number of spherical harmonic coefficients
- Output – Magnetic Field Mappings

Potential Source Surface Model



Potential Source Surface Model



Closed field lines shown are those that pass through the Neutral Line at the Source Surface Radius.

Summary

- The metric for the Heliospheric Tomography model is a second attempt at creation and application of a standard and repeatable metric.
- Blind test (no fine tuning)!
- Fine tuning of metrics is required in collaboration with the operational agencies and researchers.
- First steps, more to come.